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DESCRIPTION

DIFFERENTIAL SIGNAL TRANSMISSION CABLE

The present application is based on Japanese patent application No.2004-194156, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a differential signal transmission cable used in a bending portion of small-size electronic devices, and in particular, to a differential signal transmission cable excellent in electrical and mechanical properties and suitable for transmitting image signals of liquid crystal displays of mobile phones.

BACKGROUND ART

In cables used for signal transmission of small-size liquid crystal displays such as those of notebook PCs, mobile phones, etc., electrical properties such as EMI (electromagnetic interference) prevention, low skew (low difference in transmission delay between pairs), etc. are required. Also, because of wiring via a small hinge whose hole diameter is **5** mm or less, making small diameter cables has become important.

FIG.**1** illustrates an example of structure of a micro coaxial cable used in such applications. This micro coaxial cable **10** comprises, sequentially around an inner conductor **11** made of Sn-plated copper wires, etc., an insulation **12** made of PFA (Teflon (trademark)) resin, etc., an outer conductor **13** made of Sn-plated copper wires, etc., and a sheath **14** made of polyester,

etc., in which its outside diameter is on the order of 0.35 mm (e.g., see Japanese patent application laid-open No.2002-352640).

Notebook PCs have transitioned from parallel to serial signal transmission, which requires stricter electrical properties than characteristics of the above micro coaxial cable, so that a twin-axial cable is applied to notebook PCs.

FIG.**2** illustrates an example of structure of a twin-axial cable. This twin-axial cable **20** comprises two parallel-arranged cores each having an inner conductor **21** made of copper alloy wires, etc. which is covered with an insulation **22** made of polyethylene, etc., an outer conductor **23** made of copper alloy wires, etc. as an outer conductor around those two cores, and a sheath **24** made of polyester, etc. (e.g., see Japanese patent application laid-open No.2003-22718).

On the other hand, present mobile phones use parallel transmission using about forty-bundled micro coaxial cables for signal transmission of their liquid crystal display. By changing this parallel transmission to serial transmission, the number of signal lines can be reduced to about ten.

Transitioning to such serial transmission may cause noise from a cable to be transmitted to a motherboard, which may result in a malfunction. For this reason, an excellent electric characteristic cable such as the twin-axial cable is indispensable.

By comparison with the micro coaxial cable, however, the twin-axial cable has low mechanical properties such as bending and twisting, which is not suitable for application to mobile phones which are subject to severe bending and twisting.

DISCLOSURE OF INVENTION

Accordingly, it is an object of the present invention to provide a differential signal transmission cable which is excellent in mechanical properties such as bending and twisting as well as electrical properties, and which is suitable for signal transmission cables for liquid crystal displays of mobile phones.

To achieve the above object, the present invention provides a differential signal transmission cable comprising a plurality of stranded cores, each comprising an inner conductor covered with an insulation; an outer conductor being spirally wrapped around the plurality of stranded cores in the opposite direction to a stranding direction of the cores; and a sheath provided around the outer conductor, where the diameter of the cable is 1.0 mm or less.

The above plurality of stranded cores may comprise four stranded cores. Also, the pitch of stranding is preferably not more than forty times the layered core diameter.

The above inner conductors may use stranded wires of silver-plated copper alloy whose diameter is 0.05 mm or less; the above insulation may use fluorocarbon resin; and the above outer conductor may use silver-plated copper alloy stranded wires whose diameter is 0.05 mm or less.

The above sheath may be made from a fluorocarbon resin or a laminate of a copper-plated polyester tape and a polyester tape.

When the cores are stranded, filler such as polyester fiber may be located at the center. When the cores are stranded, a polyester tape, or a copper-metalized or -plated polyester tape may also be wrapped for holding shape after stranding.

The above differential signal transmission cable may be used in transmitting image signals of liquid crystal displays of mobile phones.

BRIEF DESCRIPTION OF DRAWINGS

The preferred embodiments according to the invention will be explained below referring to the drawings, wherein:

FIG.**1** is a cross-sectional view illustrating a conventional micro coaxial cable;

FIG.**2** is a cross-sectional view illustrating a conventional twin-axial cable;

FIG.**3** is a cross-sectional view illustrating one embodiment of a differential signal transmission cable according to the invention;

FIG.**4** is a schematic view for explaining a testing method of bending properties; and

FIG.**5** is a schematic view for explaining a testing method of twisting properties.

BEST MODE FOR CARRYING OUT THE INVENTION

FIG.**3** illustrates one embodiment of a differential signal transmission cable according to the invention. This differential signal transmission cable **30** comprises four stranded cores, each comprising an inner conductor **31** covered with an insulation **32** of fluorocarbon resin; an outer conductor **33** being spirally wrapped around the four stranded cores in the opposite direction to a stranding direction of the cores; and a sheath **34** formed around the outer conductor **33**. Here, the diameter of the cable is **1.0** mm or less, so that it passes via

a hinge of a mobile phone; it is subject to being twisted repeatedly; the number of signal transmission wires increases as liquid crystals are made finer, and so on.

The inner conductor **31** may comprise silver-plated copper alloy stranded wires. It is preferred that the silver-plated copper alloy wires are of higher conductivity, but since mobile phone harnesses are used on the order of **100** mm, silver-plated copper alloy wires may be of **70** % IACS or more. It is also preferred that the tensile strength is higher, but may be **700** MPa or more. The thickness of the silver plating may be on the order of **1** μm so that it is used mainly in a band of **800** MHz-**1.9** GHz, and at a maximum of around **6** GHz.

The insulation **32** is desirably a material which can be extruded thin, and which has a stable dielectric constant and dielectric loss tangent in a frequency band of up to **6** GHz, especially **800** MHz-**1.9** GHz. Desirable for such a material is fluorocarbon resin, more preferably, PFA (perfluoroalkyl-tetrafluoroethylene copolymer), TFE/HFP (tetrafluoroethylene-hexafluoropropylene copolymer (**4**- and **6**-fluorinated)), or PTFE (polytetrafluoroethyloene (**4**-fluorinated)). The thickness is desirably adjusted to a thickness whose characteristic impedance is **90-100** Ω between diagonal cores. Surface treatment may be made to the insulation **32**. It is acceptable to make a high electrical-conductivity metal (e.g., copper) layer on the surface of the insulation **32**. It can be sputtering or plating.

The pitch of stranded cores is desirably not more than forty times the layered core diameter. By taking the pitch to be not more than forty times the layered core diameter, use in

a mobile phone can reduce effects on a transmitting/receiving circuit. During stranding, polyester yarn **35** may be located at the center. Further, a polyester tape, or a copper-metalized or -plated polyester tape may also be wrapped for holding shape after the stranding.

The outer conductor **33** is desirably the same material as that of the inner conductor, but may be a different material therefrom. The wrapping direction is preferably the opposite direction to a stranding direction of the cores, which results in structural stability. This is because, in case the wrapping direction is the same as a stranding direction of the cores, the outer conductor falls into a groove formed by the stranding of the cores, and thereby becomes unstable. It is noted that, even in case the wrapping direction is the same as a stranding direction of the cores, there is no problem caused if the outer conductor does not fall into a groove formed by the stranding of the cores. Also, double spiral wrapping of the outer conductor **33** enhances shielding characteristics.

The sheath **34** may be made of a fluorocarbon resin or a laminate of a copper-plated (-metalized) polyester tape and a polyester tape. It is noted that it is not limited thereto if a material which is thin and unaffected by repeated bendings is used.

Examples

Using materials, thicknesses and wire diameters shown in Table **1**, a differential signal transmission cable illustrated in FIG.**3** was fabricated, and bending and twisting properties were assessed.

TABLE 1

Example	Inner conductor	Insulation		Tape wrapping	Outer conductor		Sheath	
	Configuration	Material	Thickness		Configuration	Wire diameter	Material	Outside diameter
1	7/0.025 mm	PFA	0.05 mm	none	Spiral wrapping (single)	0.025 mm	PFA	0.57 mm
2	7/0.025 mm	PFA	0.05 mm	none	Spiral wrapping (single)	0.03 mm	PFA	0.58 mm
3	7/0.03 mm	PFA	0.06 mm	none	Spiral wrapping (single)	0.025 mm	PFA	0.66 mm
4	7/0.03 mm	PFA	0.06 mm	none	Spiral wrapping (single)	0.03 mm	PFA	0.67 mm
5	7/0.04 mm	PFA	0.08 mm	none	Spiral wrapping (single)	0.03 mm	PFA	0.75 mm
6	7/0.04 mm	PFA	0.08 mm	none	Spiral wrapping (single)	0.04 mm	PFA	0.77 mm
7	7/0.025 mm	PFA	0.05 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.025 mm	PFA	0.59 mm
8	7/0.025 mm	PFA	0.05 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.03 mm	PFA	0.60 mm
9	7/0.03 mm	PFA	0.06 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.025 mm	PFA	0.68 mm
10	7/0.03 mm	PFA	0.06 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.03 mm	PFA	0.69 mm
11	7/0.04 mm	PFA	0.08 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.03 mm	PFA	0.77 mm
12	7/0.04 mm	PFA	0.08 mm	Cu-plated PE tape*1	Spiral wrapping (single)	0.04 mm	PFA	0.79 mm
13	7/0.025 mm	PFA	0.05 mm	none	Spiral wrapping (single)	0.025 mm	PFA	0.53 mm
14	7/0.025 mm	PFA	0.05 mm	none	Spiral wrapping (single)	0.03 mm	Composite PE tape*2	0.54 mm
15	7/0.03 mm	PFA	0.06 mm	none	Spiral wrapping (single)	0.025 mm	Composite PE tape*2	0.62 mm
16	7/0.03 mm	PFA	0.06 mm	none	Spiral wrapping (single)	0.03 mm	Composite PE tape*2	0.63 mm
17	7/0.04 mm	PFA	0.08 mm	none	Spiral wrapping (single)	0.03 mm	Composite PE tape*2	0.71 mm
18	7/0.04 mm	PFA	0.08 mm	none	Spiral wrapping (single)	0.04 mm	Composite PE tape*2	0.73 mm
19	7/0.025 mm	PFA	0.05 mm	none	Double spiral wrapping	0.025 mm	PFA	0.62 mm
20	7/0.025 mm	PFA	0.05 mm	none	Double spiral wrapping	0.03 mm	PFA	0.64 mm
21	7/0.03 mm	PFA	0.06 mm	none	Double spiral wrapping	0.025 mm	PFA	0.71 mm
22	7/0.03 mm	PFA	0.06 mm	none	Double spiral wrapping	0.03 mm	PFA	0.73 mm
23	7/0.04 mm	PFA	0.08 mm	none	Double spiral wrapping	0.03 mm	PFA	0.81 mm
24	7/0.04 mm	PFA	0.08 mm	none	Double spiral wrapping	0.04 mm	PFA	0.85 mm

Cu-plated PE tape*1: Cu-plated polyester tape
Composite PE tape*2: Cu-plated polyester tape + polyester tape

Bending properties were assessed by a testing method illustrated in FIG. 4. This testing method comprises connecting four inner conductor cores of one cable in series to form a test

sample 42, and attaching thereto a weight 43 of 50 gf; and bending left and right (the bending angle is 90 degree) with a radius of 2 mm at a testing speed of 30 times/min until breaking, and measuring the number of times until breaking.

Twisting properties were assessed by a testing method illustrated in FIG.5. This testing method comprises connecting inner conductors in series to form a test sample 53, and attaching thereto a torsion chuck 51 (twisted side) and a torsion chuck 52 (fixed side); and repeating twisting the test sample 53 in the 180-degree left and right directions (1)-(4) with a twisting distance of 20 mm, with a weight of 50 gf, at a testing speed of 30 times/min until breaking, and measuring the number of times until breaking.

The result of measuring bending and twisting properties shows that the lifetimes of bending the differential signal transmission cables of Examples 1-24 were all more than 20,000 times. Also, the lifetimes of twisting the differential signal transmission cables of Examples 1-24 were all more than 200,000 times.

Comparative Examples

Using materials, thicknesses and wire diameters shown in Table 2, a micro coaxial cable illustrated in FIG.1 and a twin-axial cable illustrated in FIG.2 were fabricated, and bending and twisting properties were assessed.

TABLE 2

Comparative example	Structure	Inner condcutor			Insulation		Outer conductor		Sheath	
		Configuration	Wire diameter	Material	Material	Thickness	Configuration	Material	Material	Outside diameter
1	micro coaxial cable	stranded wires	7/0.025 mm	Sn-plated copper alloy	PFA	0.06 mm	spiral wrapping	Sn-plated copper alloy	PFA	0.34 mm
2	twin axial cable	stranded wires	7/0.03 mm	Sn-plated copper alloy	PFA	0.056 mm	double spiral wrapping	Sn-plated copper alloy	composite PE tape*3	major axis 0.52 mm minor axis 0.32 mm
3	twin axial cable	stranded wires	7/0.03 mm	Sn-plated copper alloy	PFA	0.056 mm	braid	Sn-plated copper alloy	composite PE tape*3	major axis 0.52 mm minor axis 0.32 mm

Composite PE tape*3: copper-metalized polyester tape + polyester tape

Comparative Example 1 bundled four cables, and Comparative Examples 2 and 3 bundled two cables, which were followed by connecting inner conductors in series, and bending and twisting assessment tests were performed.

As a result, the lifetimes of bending Comparative Examples were all more than 10,000 times, but some did not reach 20,000 times. Also, the lifetimes of twisting Comparative Example 1 were more than 20,000 times, but some of Comparative Examples 2 and 3 did not reach 10,000 times.

It could be verified from the above results that the samples of Examples 1-24 were excellent in bending and twisting properties, compared with the samples of Comparative Examples 1-3.

INDUSTRIAL APPLICABILITY

The present invention can provide a differential signal transmission cable which is excellent in mechanical properties such as bending and twisting. Accordingly, the invention can be suitably used in signal transmission cables for liquid crystal displays of mobile phones.